MASTER OF SCIENCE IN APPLIED PHYSICS

EXPERIMENTAL DETERMINATION OF PARAXIAL RAY TRANSFER MATRICES AND CARDINAL POINTS OF COMPLEX OPTICAL SYSTEMS BY MEANS OF FINITE CONJUGATE IMAGING

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The Lineate Imaging Near-Ultraviolet Spectrometer (LINUS) uses three complex lens systems to focus an image from distances on the order of several kilometers onto the image intensifier of an ultraviolet camera. These images can then be analyzed to characterize the atmospheric distribution and concentration of sulfur dioxide (SO_2). The lenses purchased for LINUS were corrected for spherical aberrations but due to the lack of detailed knowledge about the lenses, their chromatic aberrations could not be readily predicted. The project presented in this thesis was performed with the goal of experimentally quantifying the chromatic aberrations of each of LINUS's lens systems.

The matrix method of representing paraxial optical systems was used to determine relationships between object and image distances for different lens systems. These relationships were manipulated to give equations for the matrix elements of the lens system in terms of readily measurable parameters. Once the matrix elements are known, all of the cardinal points can be readily predicted. This method will, in theory, quantify the chromatic aberrations of each lens system. The method was validated with simulations and measurements taken on a lens of known focal length. Finally, the LINUS lens systems were characterized at 220, 300, 334, and 370 nm.

KEYWORDS: Near-Ultraviolet Spectroscopy, Complex Lens Systems, Matrix Method

THE NAVAL POSTGRADUATE SCHOOL'S SMALL ROBOTICS TECHNOLOGY INITIATIVE: INITIAL PLATFORM INTEGRATION AND TESTING

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The Naval Postgraduate School's Small Robotic Technology (SMART) Initiative is an ongoing research effort within the Combat Systems Science and Technology Curriculum that engages in forward-looking applications of small robotic technology for military employment. The goal of the program is to develop a multipurpose robotic platform that is capable of hosting varied sensor packages for military research. This thesis successfully modified a Foster Miller Lemming tracked vehicle. Payload volume was increased to allow for ease of systems testing and access while incorporating a method for deploying varied sensor modules on a towed sled. Original micro-controller hardware has been replaced with a COTS system that allowed for simplified interfacing with a Honeywell digital compass and a Motorola G.P.S. card. Communications with the robot were provided through the Internet via a modem. A control interface for use on a personal computer was implemented by creating a JAVA application; the control interface has also

been converted to a JAVA applet that the robot is capable of downloading to a user via a web interface. Follow on research will fully integrate the robot with a variety of sensor packages including a synthetic array seismic sonar, visual and infrared devices and chemical detection devices.

KEYWORDS: Robotics, Autonomous, Micro-Controller, Embedded Processor, Differential GPS, Electronic Compass, Man-portable

THE DESIGN AND OPTIMIZATION OF A POWER SUPPLY FOR A ONE-METER ELECTROMAGNETIC RAILGUN

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A naval electromagnetic railgun would be a considerable asset against a littoral environment. By accelerating projectiles to 3 km/s, a naval railgun would be capable of reaching 300-400 nautical miles. Problems such as rail erosion, energy storage and fire control prevent the railgun from becoming a weapon to date. At the Naval Postgraduate School, the Physics Department continues to investigate and develop concepts to overcome these challenges. As part of the methodology, previous students built a one-meter railgun system for experimentation. The existing 1.6 mF power supply is insufficient to fire this railgun effectively. To design a sufficient power supply a MATLAB code was created to simulate a generated current pulse and to predict the subsequent railgun performance. Interrelated factors such as railgun geometry, muzzle velocity, current density and contact surface area were taken into consideration. Also, tradeoffs in capacitance, projectile mass and residual current were weighed against one another to achieve desired railgun performances. From numerous simulations, this study determined that the one-meter railgun with a 21.5 mF power supply could fire a 0.158-kg projectile at a velocity of 1 km/s, and leave a residual current of only 4% of the initial energy once the projectile exits the rails.

KEYWORDS: Navy Electric Weapons, Electromagnetic Railgun, Railgun Power Supply, Electromagnetic Launch Technology, Pulsed Power Supply

ABSOLUTE CALIBRATION TECHNIQUES FOR UV SPECTROSCOPY BASED UPON PLATINUM EMISSION LINE SPECTRA

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Imaging spectrometry requires precise knowledge of wavelength in order to perform various spectral analyses. This thesis project was tasked with performing wavelength calibration as part of the ongoing development of the Naval Postgraduate School's Lineate Imaging Near Ultraviolet Spectrometer (LINUS). This calibration was necessary for the ability of LINUS to detect, to classify, and to quantify several different chemical species by observation over the near-ultraviolet wavelength band of 200 to 400 nm.

Experiments were conducted to detect diffracted emission lines from a platinum hollow cathode lamp by using the LINUS optical train and five different UV filters. A Matlab program was developed to compare the catalogued wavelengths of this known ultraviolet source with the emission line positions observed on the LINUS detector. Affine transformation and cross-correlation of the data produced wavelength calibration curves for the LINUS detector in each of the five associated UV wavelength regions.

KEYWORDS: Calibration, Hyperspectral, Sensors, Spectral Imaging, Spectrometer, Remote Sensing, Ultraviolet

A FREE ELECTRON LASER WEAPON FOR *SEA ARCHER*

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The immediate threat of any surface combatant is the Anti-Ship Cruise Missile with stealthy, sea-skimming characteristics that reduce the time for any defensive weapon system to react. With the importance of littoral warfare, this problem is exacerbated as missiles can also be launched from land. The Free Electron Laser (FEL) will be able to meet the threat using its speed of light engagement with high hit probability, low utilization cost and unlimited firing capability.

Sea Archer is a conceptual design for a 181 m long Surface Effect Ship, displacing 13,500 tons, that can achieve speeds up to 60 knots. Its main role is to act as a small aircraft carrier with an air wing of unmanned combat air vehicles, unmanned air vehicles, and helicopters. The proposed date for employment is 2020. To provide self defense, a layered defense concept was proposed and the FEL weapon is to be the inner layer defense.

It is shown that the requisite power would be a beam output of 1.5 MW operating in the 1μm wavelength. This minimizes the effect of atmospheric attenuation, thermal blooming and turbulence. The system proposed will be installed on the *Sea Archer* within a volume of 12 m by 4m by 2m with an expected weight of 55 tons. It will have two beam directors optimizing the coverage angle of the ship. The system will be drawing power from energy storage devices, which enables the weapon to fire up to a total of 10 targets or 60 seconds of engagement before recharging is required.

KEYWORDS: Free Electron Laser, Directed Energy Weapon, *Sea Archer*

SIMULATIONS OF THE PROPOSED TJNAF 100 KW FREE ELECTRON LASER AND COMPARISON WITH TJNAF LOW POWER EXPERIMENTS

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One transitional step for the development of a 1 MW power directed energy weapon is the proposed l00 kW upgrade of the Thomas Jefferson National Accelerator Facility's Free Electron Laser (FEL). To improve the performance of the FEL, the use of the step-taper undulator is explored. Steady-state gain, final steady-state power, and the induced electron spread as a function of desynchronism and taper rates are determined. Comparisons are made to the conventional periodic and linearly tapered undulators. The multimode simulations used showed that the TJNAF 100kW FEL is feasible. Simulations results with $Q = 10$ show that the inverse step-taper undulator $D = -p$ achieved the highest final power of 190 kW at a desynchronism value of $d = 0.01$, while maintaining the induced energy spread well below the engineering limit. The validity of our results is verified against experiments conducted in the TJNAF FEL facility. The simulations and the experimental data are in good agreement and consistent with analytic theory.

KEYWORDS: Free Electron Laser, Desynchronism, Step-taper Undulator

OPTICAL CHARACTERIZATION OF SOOT PROPERTIES IN A FILM-COOLED KEROSENE/OXYGEN EXHAUST PLUME

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The soot mass loading and associated optical properties in the exhaust of a film-cooled liquid rocket engine burning gaseous oxygen with hydrocarbon fuels were measured. The exhaust plume without film cooling was characterized over an oxygen-to-fuel (O/F) range of 0.4 to 1.5 to find soot properties expected in the fuel-rich film region. The derived baseline soot production curves for JP-8 and JP-8+100 were similar to kerosene. Soot levels derived for JP-10 were much higher than JP-8 and the predicted values over the same O/F range. Operating the engine with a core O/F of 1.5, film cooling mass-flow percentages were varied over a range of 6 to 21% of total reactants. Film layer thickness and soot mass loading both increased as percent film cooling increased. The rocket engine was operated with and without film cooling during the same run to obtain properties for the plume core and plume core with film cooling under nearly identical engine operating conditions. A vortex ring segment was used to tangentially inject the film layer. A multi-wavelength, fiberoptic transmission technique, using the transmission ratio of five wavelengths (from the visible to the near IR) through the exhaust plume, was used to determine the amount of soot present.

KEYWORDS: Soot Measurement, Kerosene/Oxygen Liquid Rocket Engines, Film-Cooled